

# In-Situ Comparison for 2.5D Treemaps

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**Abstract:** 2.5D treemaps can be used to visualize tree-structured data using the height dimension for additional information display. For tree-structured and time-variant data though, changes or variants in the data are difficult to visualize. This paper presents an in-situ approach to depict differences between two versions (original and comparative state) of a data set, e.g., metrics of different revisions of a software system, in a single 2.5D treemap. Multiple geometry variants for the in-situ representation of individual nodes, especially concerning height, area, and color, are presented and discussed. Finally, a preliminary study for the simultaneous change of attributes in height and area is described, hinting that arrow pattern help to clarify reading direction.

## 1 INTRODUCTION

Most use cases for visualization using treemaps (Johnson and Shneiderman, 1991) have one aspect in common: the input data sets representing systems or phenomena to be analyzed are in a state of flux. For example, to understand and evaluate the development of a software system using treemaps (Bohnet and Döllner, 2011), it is required to be able to analyze the data collected over time, such as the extent of code changes or the number of developers involved. Thus, the visualization of changes over time is an important aspect for visual analytics of system evolution. If each evolutionary step can be represented as a tree-structured data set, one goal is to depict corresponding changes between an *original state* to a *comparative state* using differences of attribute values (Fig. 1).

**Problem Statement.** While approaches for visualization of changing tree-structures over time can be applied for 2D treemaps (Tu and Shen, 2007; Gómez et al., 2013), early techniques for 2.5D treemap visualization (Bladh et al., 2004; Trapp et al., 2013) only support the presentation (mapping and rendering) of a single data set or state at any time. In 2.5D treemaps “extruded [...] shapes allow for a 3D attribute space mapping to 3D substitutes within a treemap’s two-dimensional reference space, hence, 2.5D. In contrast, various visualization techniques such as treecube or 3D polar treemap (Johnson, 1993) are classified as 3D treemap that lay out hierarchy elements within a three-dimensional reference space (Schulz et al.,

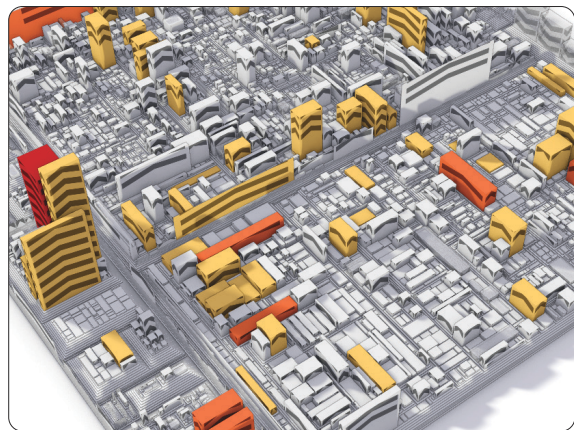


Figure 1: A 2.5D treemap depicting two revisions of metrics of a software system (Elasticsearch<sup>1</sup>) using a basic in-situ template for the visual display of changes in height: an arrow pattern. A more prominent color indicates code units that were touched by only a few (yellow) or a single (red) developer(s). The height of elements depict the cyclomatic complexity of the represented code unit. Finally, an increase or decrease in height is indicated by upwards or downwards pointing arrow pattern respectively.

2011). However, it should be noted that the term 3D treemap is often used to denote 2.5D treemap as well.” (Limberger et al., 2017)

There are several approaches to visualize differences or variances in a data set that are applicable to 2.5D treemaps. For example, *small multi-*

<sup>1</sup>Open Source, Distributed, RESTful Search Engine with over 42.000 commits: [github.com/elastic/elasticsearch](https://github.com/elastic/elasticsearch)

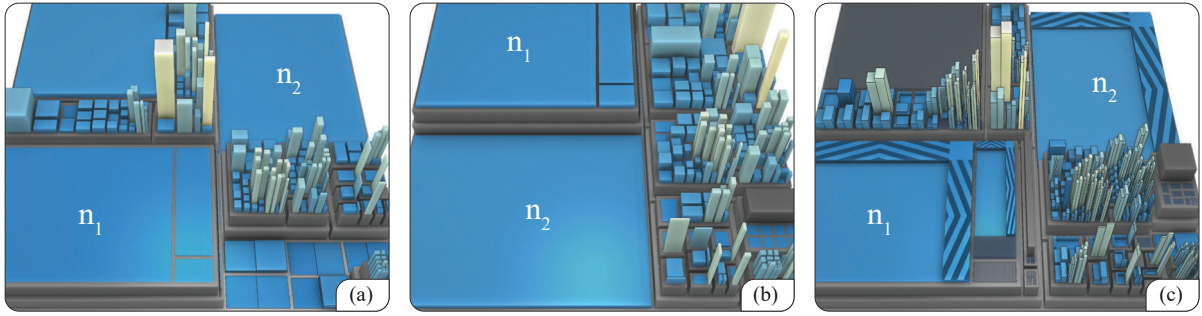


Figure 2: An exemplary in-situ visualization (c) shows the changes of two nodes  $n_1$  and  $n_2$  in mapped height and area according to the differences in attribute values computed from the original state (a) and the respective comparative state (b).

ples (Scheibel et al., 2016) can be used for the comparison of states or attribute mappings. To perceive and locate changes, two depictions must be compared, which might be a tedious and error-prone task. To retain location and to visualize trends within changes of attribute values, Würfel et al. applied the rendering of *natural metaphors* to single or multiple items of a 2.5D treemap (Würfel et al., 2015). While it supports visualization of change locations and trend directions, it lacks capabilities to estimate the amount or degree of attribute value changes. Besides static depiction, changes can be communicated using *animated transitions* (Fekete and Plaisant, 2002), which effectiveness is limited by the number of changes that are animated simultaneously.

Considering the treemap layout, the *EvoCells* rectangular layouting algorithm applies the evolution in topology and associated weights of a tree-structured dataset onto an initial layout is (Scheibel et al., 2018). However, layout changes can cause confusion and disorientation, especially when concerning the addition or removal of nodes. Even if the remaining layout remains stable, the size changes of the individual nodes resulting from the new layout might distract from changes that may occur in the respective attributes, such as item color or height.

A recently published flow-graph technique, Temporal Treemaps (Köpp and Weinkauff, 2019), allows to visualize topology changes in tree-structured data. The authors indicate that encoding changes in additional attributes might be possible using their technique. However, we find them to more or less discard the inherent structure of classical treemaps and, by that, the mental model typically associated with the depicted topologies.

With respect to the approaches above, we argue for a concept and technique to visualize changes or trends using a single 2.5D treemap that enables users to estimate the location, direction, dimension, and quantity of changes without the need for animation.

**Approach & Contributions.** We argue that 2.5D treemaps (using a common layouting strategy) can be extended to presents two versions of mapped data in a single visual representation (Fig. 2): Using an “*in-situ*” (or “in position”) mapping approach, changes between two data representations can be visualized by depicting differences in height, area, and color of the individual treemap items, simultaneously. We first analyze, explore, and discuss the design space for visualizing differences between two treemap items. Based on the results, a developed prototypical in-situ implementation (integrated into a software tool for the visualization of static software system structures) represents the basis to perform a preliminary correlation study to evaluate early results.

## 2 IN-SITU TREEMAP DESIGN

To visualize two states of a tree-structured data set using a single 2.5D treemap, we partially deviate from the traditional 2.5D cuboid mapping of a treemap item. Depending on the visual variables subjected to change, e.g., color, area, or height as well as combinations thereof, it maybe necessary to use a more complex geometric structure. To this end, we discuss so-called *in-situ templates* for the respective comparative cases.

The taxonomy for visual comparison (Gleicher et al., 2011) suggests that every comparison uses either juxtaposition, superposition, or explicit encodings for the visual display of original and comparative states. Our overall approach uses a superposition, that is, a single treemap. Each of the in-situ templates, however, utilize one of the three approaches, thus, the resulting treemap might be composed of either juxtapositioned, superpositioned, or explicitly encoded comparisons of one or more attributes.

In general, the in-situ templates are intended to represent leaf nodes and cannot simultaneously depict

inner nodes. When using a level-of-detail technique that is linked directly to the data’s tree-structure, in-situ templates might be used for inner nodes as well. In that case, the templates should be adjusted to account for discriminability of leaf and inner nodes (Elmqvist and Fekete, 2010; Limberger et al., 2017).

Please note that all of the following images are captured from a prototypical implementation and were adjusted in contrast and color for print.

## 2.1 Changes in Item Color

For a single cuboid, we map a data attribute to a color for both the original data and for the comparative data, and explore how best to display these two colors on the same cuboid (Figure 3 summarizes a few design alternatives for changes in color). By changing the color alone, it is not required to deviate from a cuboid geometry as a representation of a tree node. Either color gradients, distinct colors, or color patterns can be used. As shown in Figure 3(a), it can be difficult to recognize the original and comparative color in a color gradient or to perceive any change in color at all. Furthermore, the intermediate colors have to be computed by interpolating the underlying attribute values and mapping the resulting values to color by applying the treemap’s color scale. This process often causes incomprehensible color gradients.

If the cuboid is split vertically instead as shown in Figure 3(b), each half can distinctively encode one of the two attribute values by its color. It should be noted, that a reading direction is required in order to unambiguously associate the colors to original and comparative state. As Western culture generally reads from left to right, we decided to arrange colors for the original and comparative values accordingly. Besides, the template is only beneficial if padding between siblings is applied. Otherwise, the halves of a split cuboid might be indistinguishable from two contiguous cuboids. To counter this, the cuboid could be split diagonally though emphasizing the comparative value at the cuboid front (Fig. 3(c)).

Alternatively, color patterns by means of procedural texturing can be used (Fig. 3(d) and 3(e)). This,

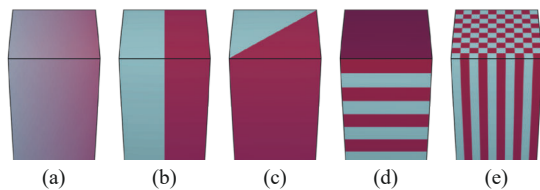


Figure 3: In-situ templates for depicting changes between an original (bright cyan) and a comparative (dark magenta) value of an attribute mapped to color.

however, might lead to perception problems due to visual clutter (e.g., very small cuboids). Likewise (especially with the pattern in Figure 3(e)), it is difficult to establish an intuitive reading direction since no distinct beginning and end are recognizable.

## 2.2 Changes in Item Height

For the communication of differences in attribute values mapped to height we discuss three in-situ templates applying a stacked, combined, and side-by-side (vertical split) arrangement of two distinct cuboids. This is in part conceptually similar to the metaphors *property towers* (Steinbrückner and Lewerentz, 2010) as well as *bricks* (Wettel and Lanza, 2008)—both capable of encoding multiple states of an attribute value.

**Stacked Arrangement.** If the area of a node remains unchanged, two cuboids can be stacked on top of each other (Fig. 4(a)). This approach tends to increase the average height of treemap items and thereby increases occlusion noticeably. Although the hidden nodes could be made visible to the user through navigation (e.g., camera rotation or tilt), we prefer to keep occlusion in 2.5D treemaps to a minimum (padding, heightened elevation of the virtual camera, etc.). Alternatively, transparency can be used though, if latest order-independent transparency rendering (Enderton et al., 2010) are not available or feasible, transparency most likely causes visual clutter. Furthermore, it is difficult to compare the heights of the two cuboids to one another and, in order to emphasize the junction between the cuboids (especially if they have the same color applied) we advise to use a levitation-like effect as depicted in Figure 4(b).

**Combined Arrangement.** Given that the area of a node is the same for its original and comparative state (as with the stacked arrangement), the height of

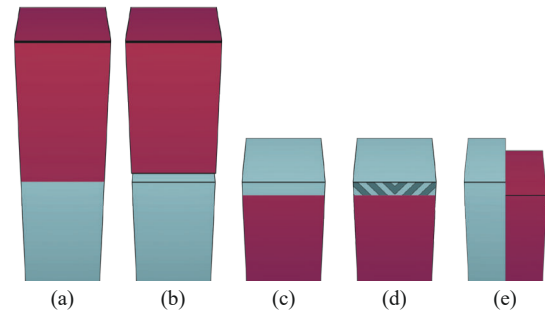


Figure 4: In-situ templates for depicting changes between an original (bright cyan) and a comparative (dark magenta) value of an attribute mapped to height.

cuboids can be nested (Fig. 4(c)). Given a unique ordering (e.g., the comparative state item is displayed within the first), this approach can only be used for reductions. This can be circumvented by using, e.g., an arrow pattern encoding the direction of change (Fig. 4(d)). Alternatively or in addition to that, transparency could be used to encode a decrease in height: the upper cuboid (depicting the amount of reduction) would be displayed transparent. This is, again, most likely constrained to the rendering capabilities since it requires order-independent transparency.

**Side-by-Side Arrangement.** The two states can be represented by cuboids arranged next to each other (Fig. 4(e)), analogously to the vertical split for color change. The overall height mapping of the treemap remains unaffected and, similar to Section 2.1, the original and comparative state should be displayed on the left and right respectively. With this arrangement, height changes can be identified more effectively, since the respective cuboids are depicted directly next to each other. Due to the side-by-side arrangement and, thus, the more explicit reading direction, this template might be easier to read in general (Talbot et al., 2014) but is not rotation-invariant. Another disadvantage of this arrangement is the reduced area available for mapping which requires specific treatment in order to remain comparable to items of unchanged nodes. In practice though, these are negligible since rotational navigation does not benefit exploration (except for resolving occlusion) and area is mostly used to indicate a node’s magnitude.

## 2.3 Changes in Item Area

The change in the area of two nodes can be represented in different ways. A straight-forward approach would be to arrange both cuboids, side-by-side (Fig. 5(a)) and consider their area mapping independently of one another. Two cuboids of different extent and aspect ratio are difficult to compare in terms of their area, especially if the depth of the cuboid is shortened by perspective. Another problem is the

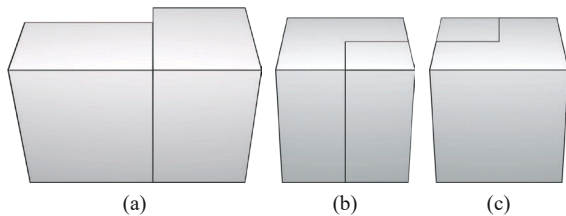


Figure 5: In-situ templates for depicting changes between two values of an attribute mapped to area.

increased space necessary for the treemap which decreased the size of all items. Figure 5(b) shows how a cuboid of smaller area can be positioned within a cuboid of larger area at the bottom right corner. This solves the aspect ratio issue, but is only feasible for nodes of a more square-like aspect ratio.

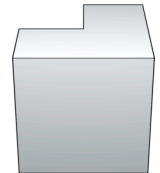
Embedding the node with the smaller area within the node of larger area poses the following problem: it is no longer possible to know which of the areas belongs to which state. This problem can be approached by introducing a reading direction, as described in Section 2.1 and 2.2. Here, the reading direction of the representation is adapted to a *local reading direction* as follows: the node of the reference state is located at the top left and the node of the changed state at the bottom right. If the area decreased, the area-wise small cuboid is at the bottom right, but if the area has increased, the square-shaped cuboid is at the top left (Fig. 5(c)).

## 2.4 Depicting Multiple Changes

Previous sections discussed how changes of a single visual variable can be communicated to a user. However, it is more probable that two or three variables change simultaneously.

**Color-Height and Color-Area Changes.** Changes in color mapping can be easily integrated into the approach for height and area changes. For this, the corresponding cuboid of a state is colored according to its mapping. The cuboid positioning is retained, thus the reading order described previously is preserved.

**Height-Area Changes.** Similar to changes in color, changes in item height can be integrated into the templates for the representation of area changes. The template is divided into two items, each representing the height of the respective nodes of the respective state, e.g., the smaller cuboid represents the height of the node with the smaller area. The prism with the L-shaped footprint surrounding this cuboid represents the height of the node with the larger area (Fig. 6(a)). However, as shown in Figure on the right, this approach, in combination with the reading direction proposed in Section 2.3, introduces occlusions: the original state can no longer be perceived. To avoid such occlusions, the notion of reading direction is extended as follows. In addition to the distinction between original state and comparative state, it should





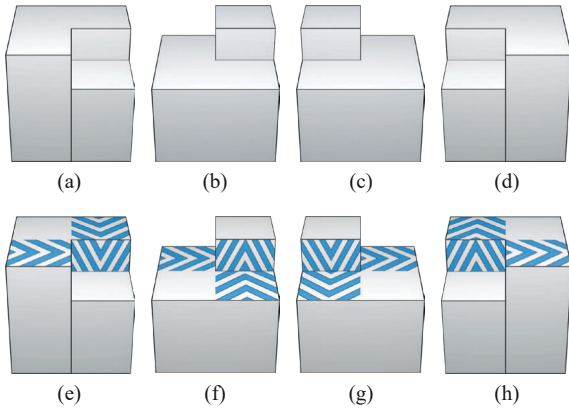
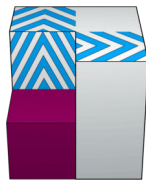


Figure 6: Templates for visualization of simultaneous height and area changes: height and area decrease (a, e), height increase and area decrease (b, f), height decrease and area increase (c, g), and height and area increase (d, h).

be ensured that the presentation remains free from obfuscation. To this end, the original state is arranged on the left and the comparative state on the right, and the lower item is displayed at the front and the higher item at the back. The resulting four orientations are shown in Figure 6 (top row).

In order to increase readability we added procedural textures that indicate the direction of the surface and height changes. Figure 6 (bottom row) shows the representations using arrow textures indicating the directions in which the area and height have changed from the original state to the comparison state.

**Color-Height-Area Changes.** Coincident changes within all three visual variables can be represented using, e.g., procedural texturing in the height and area change templates described above. The objects in the geometries, which already indicate the height change, are colored according to the color of the state (as shown in the Figure on the right). The positioning and texturing of the items are preserved according to the principles introduced for simultaneous height and area changes. This ensures the assignment of the two states and avoids occlusions.



## 2.5 Hierarchy Changes & Quantization

A special case for in-situ visualization are changes within the data hierarchy between two states, i.e., nodes are added, removed, or moved to different hierarchy levels (Köpp and Weinkauff, 2019). The presentation of these nodes is difficult because a respective corresponding node is missing. These cases can

be visually communicated using transparency rendering, e.g., added nodes are displayed with transparent surface, while dropped nodes are only displayed as wire-frame.

The way in which the amount of changes are presented is of particular importance for comparative visualizations. Using an exact mapping of changes theoretically allows for an accurate reading of differences, but makes it difficult to detect minimal differences between two states at the same time. Further, perception is more difficult for 2.5D presentations, since the difference mapping is additionally distorted by perspective projection. To counter-balance these effects, difference values can be quantized. This impacts accuracy, but might increase readability, e.g., by making minimal changes visible.

## 3 IMPLEMENTATION REMARKS

This section explains how the presented approach can be integrated into existing systems and frameworks for treemap visualization. Such integration basically comprises the following five steps performed prior to rendering: (1) import data sets for the two states to compare, (2) merge both states into a single tree representation, (3) determine changed attributes from the merged tree, (4) compute the respective maximum attribute values for layout purposes, and (5) perform layouting and geometry synthesis.

**Attribute Merging.** For each attribute, the input tree structures have an object that stores the individual values for each contained node (in the following attribute map). To represent two states per node, two attribute maps are used per stored attribute. The merging step first iterates over the nodes of the reference tree and collects the attributes of the corresponding node in the changed tree. If a node does not exist in the changed, comparative tree or if it has been moved within the tree, “null-values” are set for all of its attributes; otherwise all attribute values that the node are copied. Finally for each node of the changed tree the newly added or omitted nodes of the first pass are added to the reference tree.

**Layout Computation & Geometry Synthesis.** In addition to an attribute normalization step, the layout computation must also be adjusted to displayed all nodes in correct relation to each other. It is necessary to use the maximum value of both states at a per-node level. Although this may drastically change the layout of the in-situ treemap compared to the layout of the individual states, all the nodes are displayed

in correct proportions. For every leaf node, the data calculated in the previous steps (i.e., length, width, height, and color, for each cuboid of both states) is used to decide which of the geometries described in Section 2 are selected for mesh generation. While in most cases it is sufficient to compute absolute mesh coordinates directly, mapping area changes benefits from coordinates relative to a unit cube. This is because the in-situ template must be rotated in 90 degree increments, depending on the interplay of height and area change directions, as described in Section 2.4.

## 4 PRELIMINARY EVALUATION

To probe the effectiveness of some of the more complex in-situ templates, we conducted a brief, preliminary correlation study. Different variations of renderings of small 2.5D treemaps were created using our prototype. Each rendering comprised a prominent node of simultaneous height and area change depicted using the appropriate in-situ template (as shown in Figure 6). The amount of change varied from 25% to 50% (either increase or decrease) and no color mapping was used, resulting in mostly white cuboids with slight shading. The variations were derived from the independent variables

- *increase or decrease in height,*
- *increase or decrease in area, and*
- *with or without the use of the arrow pattern.*

Cases in which either height or area remained unchanged are not relevant for the specific in-situ template used and was ignored.

The study was executed using Google Forms<sup>1</sup>. A total of 28 participants were shown the static, precomputed renderings without randomization and, for each rendering, were asked to identify the type of change (increase or decrease) for height and area of a specific, encircled node. The group of participants included users with prior knowledge of treemaps as well as users without prior knowledge of visualization techniques in general.

For the evaluation the effectiveness was measured using a dichotomous accuracy of the answers; only the binary correctness of the identified direction/types of changes (increase or decrease) in both height and area was counted. The main goal was to derive two indicators. First, whether or not the template seems capable of communicating the direction of change (increase or decrease). Second, if a more explicit encoding of the read direction, by means of an additional arrow pattern, can increase effectiveness.

<sup>1</sup><https://www.google.com/forms/about/>

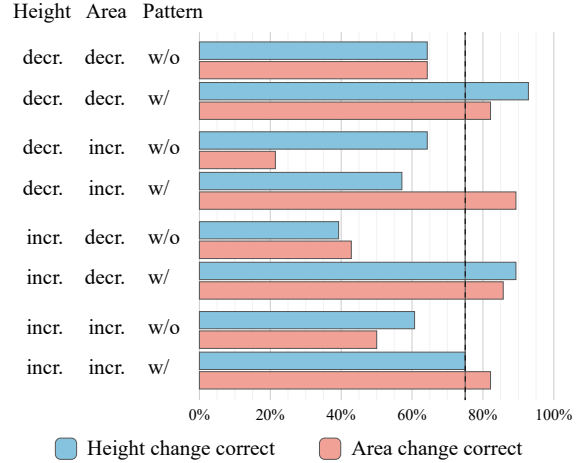


Figure 7: Results for height and area-change templates.

The accuracy measures are shown in Figure 7 and indicate that the use of arrow patterns increased the change accuracy for both height and area change (in this case over 75%). In the case of opposing changes, some participants interpreted the larger cuboid (Fig. 6(f) and Fig. 6(g)) as a small, superimposed body. In these cases, the arrow pattern seem to have the biggest impact on clarifying the reading direction. This suggest that the underlying template-design requires further improvement in order to increase accuracy.

## 5 CONCLUSIONS

This paper presents an in-situ visualization technique for depicting changes in 2.5D treemap items (such as, mapped color, height, and area) that allows for the comparison of two versions of hierarchically organized data using a single image. A brief, preliminary study hints that even for simultaneous data changes affecting two visual variables, i.e., height and area, in-situ representation might be helpful in recognizing and assessing such changes. Changes that would be difficult to perceived due to layout changes, e.g., by adding or removing large nodes in a hierarchy, can be visualized using an in-situ treemap and interpreted sufficiently by the user. Even though the in-situ representation of treemap items increases the complexity of the treemap structure, it might provide an effective alternative for the display of changes in 2.5D visualizations in general.

With respect to rendering techniques, we were able to utilize GPU-based, stochastic and order-independent transparency. First results (Fig. 8) show that, regardless of the increased hardware require-



Figure 8: In-situ utilizing transparency for height changes.

ments and the added visual complexity, transparency might be an interesting extension to the design space of in-situ templates. Moreover, we would like to evaluate the effectiveness of in-situ for large data sizes and facilitate visual-analytics tasks of expert users. Most importantly, an exhaustive and comprehensive experiment and evaluation with the presented in-situ templates is needed, also including task performance in comparison to basic 2.5D treemaps.

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